ONE SHILLING

ALL ABOUT THE TELEPHONE AND PHONOGRAPH HOW TO MAKE AND USE THEM

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ALL ABOUT
THE
TELEPHONE
AND
PHONOGRAPH.

CONTAINING

DESCRIPTION OF BELL'S AND DOLBEAR'S TELEPHONES AND EDISON'S
PHONOGRAPH.

HISTORY OF THE DISCOVERY.

DETAILS OF CONSTRUCTION AND INTERESTING EXPERIMENTS.

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ALL ABOUT THE TELEPHONE & PHONOGRAPH.

THE Telephone, an instrument by which sound can be conveyed to, it would appear, an unlimited distance—by which conversation can be carried on between persons separated by many miles of sea and land—is unquestionably one of the most marvellous of modern adaptations of scientific knowledge to practical use. The discovery and successful working of the electric telegraph has familiarised us with achievements of science which fifty years ago would have been considered miraculous, and a bare intimation of the possibility of which might, two or three centuries previously, have led the unfortunately ingenious speculator to the stake as a wizard. We can, and daily do, transmit messages to and fro between almost every part of the habitable globe

--messages which are not only read off by skilled operators as easily as the pages of a printed book, but are printed by the telegraph itself ; and to that really amazing command of the forces of nature we now add the power of transmitting, by the Telephone, the tones of the human voice, distinct articulations, perfectly pronounced words, and musical sounds, to any distance to which the necessary wires may be extended; and, by the most recent adaptation of the instrument, the Phonograph, *a message of any length can be spoken on to a plate of metal, that plate sent by post to any part of the world, and the message absolutely re-spoken in the very voice of the sender.*

So marvel follows marvel ! Voice by Telegraph is followed by voice by Post-card, and the New Year heralds the Future with a new wonder. As Tennyson has it, in the "Two Voices," (which we may now, perhaps, interpret as the natural and the telephonic voices)—

" All the years invent,
Each month is various to present
The world some new development."

In the following pages we narrate the various steps by which these wonderful results have been attained, and describe, in a popular manner, the principles of physical science on which the construction of these wonderful instruments is founded. A full description of the mechanism is also given, so that persons

possessed of mechanical ingenuity may construct for themselves apparatus sufficiently powerful to produce very remarkable results.

An account of some recent experiments of great interest, and suggestions as to further application of these wonderful inventions, are appended.

ELECTRO-MAGNETISM, AND ITS APPLICATION TO TELEGRAPHY.

An acquaintance with the leading principles of the science of electro-magnetism is absolutely necessary before any clear idea of the working of the Telephone can be obtained. The power of the "loadstone," as it is popularly designated, to attract iron and lift a mass equal to many times its own weight, has been known from remote antiquity; and it has also been known that the attractive power may be imparted by contact to iron itself, so producing what is known as an artificial magnet. Another property of iron so magnetised has long been known, although the principle has only been explained in recent times, that a bar or needle of iron so mag-

netised has two poles, one of which will, if the magnet is freely suspended, turn to the north, and that the two ends (or poles) of the magnet are alike in their power of attracting soft iron, but differing in their action on the poles of another magnet—like poles repelling, and unlike poles attracting each other.

The loadstone, or natural magnet, is now known to be one of the ores of iron, the magnetite of mineralogists. The iron is chemically combined with oxygen, and forms 72·5 per cent. of its weight. There is another ore of iron, known as hematite, which contains 70 per cent. of iron; but the difference of two and a half per cent. of iron in the ore is enough to make the difference between a magnetically inert substance, and one which may be able to lift a mass of iron equal to many times its own weight.

Sir Isaac Newton is said to have worn in a finger-ring a small loadstone weighing three grains, which would lift seven hundred and fifty grains, which is equal to two hundred and fifty times its own weight. The most powerful magnet now known is owned by M. Obelliane of Paris. It can lift forty times its own weight. Large pieces, however, do not support proportionally greater weights, seldom more than one or two times their own weight.

There are in many places in the world immense beds of magnetic iron-ore. The celebrated iron-mines of Sweden consist of it, and in Lapland there are several large mountains of it; and it is also found

in the Adirondack region in the state of New York, and in Chester County, Pennsylvania. It must not be inferred, that, because the mineral is called magnetite, all specimens possess the property called magnetism. The large masses seldom manifest any such force, any more than ordinary pieces of iron or steel manifest it; yet any of it will be attracted by a magnet in the same way as iron will be. The most powerful native magnets are found in Siberia, and in the Hartz, a range of mountains in Northern Germany.

In 1820, Professor Oersted of Copenhagen discovered that if a properly balanced magnetic needle was placed immediately under and parallel to a wire along which a current of voltaic electricity was passing, that end of the needle which was situated next to the negative side of the battery immediately moved to the west, while if the needle were placed parallel to and over the wire, the same pole moved to the east. This discovery and the result of other experiments, led to the identification of magnetism with electricity, which had long been suspected, and an almost boundless field of research was opened. The investigation of the subject was taken up with characteristic ardour and perseverance by Faraday in England, Professor Ampère of Paris, and Schweyzer of Germany; and a consideration of the influence exerted by electrical currents on magnets naturally led to the conclusion that the

neutral condition of bodies susceptible of magnetism would be disturbed by an electrical current, and this conclusion was quickly verified by experiments. When an electric current was passed at right angles to a piece of iron or steel, the latter acquired magnetic polarity, either temporary or permanent, the direction of the current determining the position of the poles, and the effect was prodigiously increased by causing the current to circulate a number of times round the bar, which then acquired extraordinary magnetic power.

In 1837, Mr. Sturgeon of Woolwich, discovered that if a copper wire were wound around a piece of soft iron, and a current of electricity sent through the wire, the soft iron would become a magnet, but would retain its magnetism no longer than while the current of electricity was passing through the coil. The magnetism developed in this way was called electro-magnetism, and the iron so wound was called an electro-magnet. The first electro-magnet was made by winding bare wire upon the soft iron. This method will not produce very strong magnets.

Professor Henry of Princetown, New Jersey, afterwards insulated the wire by covering it with silk, and was able by this means to produce very powerful magnets. On a soft iron bar of fifty-nine pounds weight he used twenty-six coils of wire, thirteen on each leg, all joined to a common conductor by their opposite ends, and having an aggregate length of

728 feet. This apparatus was found able to sustain a weight of 2,500 pounds. This electro-magnet is now owned by Yale College, Newhaven, Connecticut, United States.

The power of electro-magnets, constructed on this principle, is enormous. Mr. Joule, the eminent natural philosopher, of Salford, has constructed small electro-magnets which support masses 3,500 times heavier than themselves ; and magnets of colossal power have since been produced by Mr. Wilde of Manchester, and M. Gramme of Paris. Electro-magnets are immeasurably superior in strength to natural magnets or steel bars magnetised by contact with natural magnets. The electro-magnet generally consists of a round bar of soft iron, bent into the horse-shoe form, with an insulated wire (that is, wire covered with silk) coiled round its extremities. When a current passes through the coil, the soft iron becomes instantly magnetic ; and when the current is stopped, the power disappears as quickly as it came. A very familiar and popular scientific experiment is the sudden attraction of iron filings or small iron nails by a magnet of this description. The fragments of iron leap as it were to the magnet, and hang from it, held together by the strong magnetic force. In this position they remain so long as the electric current is passing through the wires ; but the moment it is stopped, they fall off into a heap, entirely deprived of the magnetic sympathy which an instant before made

them cluster together with such irrepressible force. It is easy to see how this power of alternately imparting and cutting off attractive power may be made available in producing motion. For instance, the teeth of a wheel may be attracted in succession, and so a rotary motion produced ; and it is evident that as the electric force may be transmitted through wires for any distance, a wheel or other apparatus at the extreme end of a line may be made to act sympathetically with a similar apparatus at the home end, by means of these transmitted “jerks,” or alternate currents or stoppages. This is the key to the whole mystery of telegraphic communication. Of course there are manifold methods of applying the power to the production of intelligible signs and other means of communication. It is not necessary for our purpose to describe these methods ; but a clear understanding of the principle is essential.

Some of our readers may not be aware that the earth itself is a huge electro-magnet, with currents of electricity perpetually circulating around it, having its poles, or the neighbourhood of the poles (or ends) at the axis of rotation—the familiar North Pole and South Pole of our geographical lesson-book. Refer back to what we have said respecting the action of one magnet on another, and it will be easy to understand why one end of the magnetised steel of the mariner’s compass always points to the north.

The next point to consider is the mode of pro-

ducing the electric current, which, by its circulation around the soft iron, forms the magnet. This electricity is produced by the action of the electric battery originally devised by the Italian philosopher, Alessandro Volta, in 1799, and sometimes known as the voltaic pile or the galvanic battery, it having originated in the investigations made by Volta into the nature of the electric action on the nervous system of animals noticed by Luigi Galvani, the great physiologist of Bologna. The original form of the battery, as devised by Volta, and modified but little during thirty years, consisted of a cell to contain a fluid, which was usually dilute sulphuric acid in which two plates of different metals were immersed: the metals used were generally plates of zinc and copper, or zinc and silver. Such plates, when first placed in the liquid, will give a very good current of electricity, but it will not last long. The reason of this is easy to understand. Whenever a current of electricity is generated by chemical action of a liquid upon two different metals, there is always some decomposition of the liquid, and this decomposition takes place upon the plates themselves; and the liberated gases *adhere to the plates, and prevent further contact with the acid*; at the same time, the gases themselves act upon the plates, and generate a current of electricity in the opposite direction. This will of course interfere with the first current; and very soon the battery is useless until the plates have

been withdrawn from the liquid. This physico-chemical process that takes place in such a battery is called the *polarisation of the plates*.

We will endeavour to describe (which is much easier than to explain, for the exact relation of chemical and electrical action is one of the problems which exercises the ablest minds in science) the action going on in a battery cell of the kind mentioned. If a plate of platinum and a plate of zinc are placed opposite each other in a vessel containing hydrochloric acid, and connected by a wire, a hissing sound will be heard coming from the cell, and bubbles of gas will be seen to rise from the platinum plate. These bubbles prove upon analysis to be bubbles of hydrogen. At the same time the zinc will begin to dissolve, forming what proves by analysis to be the chloride of zinc; and simultaneously a current of electricity travels through the wire from the platinum to the zinc. The quantity of electricity that is thus generated is strictly proportionate to the quantity of hydrogen liberated, which is also proportionate to the weight of zinc dissolved; and this, in turn, is proportionate to the surface of the metals exposed to the action of the acid.

There are many variations of the original of the battery, copper and zinc being the metals generally submitted to the action of nitric and sulphuric acids. Daniell's, Grove's, Bunsen's and Smee's, are the batteries most generally used. From the battery the

electric force is transmitted to the wires traversing the iron bar, and the magnet is produced.

Although electricity will in this manner induce magnetism, yet magnetism differs from electricity. Professor Dolbear says—"We can come to but one conclusion, that both electricity and magnetism are but forms of motion; electricity being a form of motion in ordinary matter, for it cannot be made to pass through a vacuum, while magnetism must be a form of motion induced in the ether, for it is as effective in a vacuum as out of it; electricity always needing some material conductor, magnetism needing no more than do radiant heat and light."

Magneto-electricity, discovered by Faraday in 1831, is the converse of electro-magnetism; that is, the action of a magnet induces an electric current through a wire; the opposite effect being that of electro-magnetism, by which the passage of an electric current through a surrounding coil changes a piece of soft iron into a magnet, as described above. It is magneto-electricity that is now the active power of the Telephone, as we shall see when describing the instrument in detail.

The discovery of electro-magnetism, revealing the possibility of sending intermitting currents of electric force through wires of great length, naturally attracted the attention of scientific investigators to the subject of the transmission of signals, or of communication by means of the alphabet. Previous

attempts with the aid of frictional electricity had been made, and electric shocks produced at the distance of a mile or two by Wollaston in 1747 ; by Franklin, in the following year ; at Geneva and in some parts of France ; and in 1794, Reizen of Germany employed the electric spark for telegraphing, employing a very elaborate apparatus. He made use of interrupted slips of tin foil, so arranged that the form of the letter or figure was exhibited by the sparks he transmitted. He employed 36 wires from one station to another, each one of them communicating with one of the letters or figures, and each one connected with a return wire, thus making 72 in all. Three years afterwards, Don Francisco Salvá and Senor Betancourt constructed a similar telegraph between Madrid and Aranjuez, a distance of about 26 miles, and shortly afterwards proposed to substitute the voltaic pile for the frictional electrical machine. In 1816, Mr. Francis Ronalds of Hammersmith established telegraphic communication between two stations eight miles apart, connecting two clocks, one at each station, moving exactly together, and each bringing into view one after the other the letters of the alphabet arranged upon a disc which revolved behind a screen, with an opening for one letter. Each clock was provided with two pith balls connected with an electrical machine at the other station ; and the divergence called the attention of the operator to the letter then in view. About six years previously

Ampère had pointed out the applicability of electromagnetism to the transmission of telegraphic signs ; but his plan included the use of 30 needles and 60 independent wires. Many other experiments, none attaining definite results, were made, one of the most remarkable in the direction of simplicity, being that of Steinheil of Gottengen, in 1837. He employed a single wire twelve miles long, and the signals were produced upon a series of bells of different tones, which soon became intelligible to a cultivated ear ; and the same deflections of the needle (caused by the transmitted current of electricity) which produced the sounds were also made to trace with ink lines and dots upon a ribbon of paper moved at a uniform rate. This was a great advance towards the production of a telegraph practically available ; but in the meanwhile, careful experiments were being carried on simultaneously in England and the United States which resulted in the establishment of the electric telegraph, now, with some modifications, generally employed. In June, 1837, Professor Wheatstone and Mr. Cooke (the latter of whom had had his attention directed to the subject when a student at Heidelberg) jointly took out a patent in England ; and in the following October, Professor Morse, of New York, who had been labouring at the subject for five years, took legal measures to secure a patent in the United States. In England the telegraph was first brought into active operation on the Great

Western Railway, between Paddington and West Drayton about the end of 1838 ; and in America, Morse's system was made practical use of in May, 1844, between Washington and Baltimore.

That is enough of the history of electric telegraphy for our present purpose ; and we will now briefly describe the mode of transmitting messages adopted by the respective inventors, for the purpose of assisting our readers to comprehend the working of the Telephone and Phonograph, of which we shall shortly speak. The Telephone is in fact a vocal telegraph, by which the waves of sound are conveyed from point to point, and the vibrations reproduced, just as the intermittent and varied electric shocks are transmitted and reproduced at the extremity of the wire opposite to that from which the message is dispatched. There is considerable similarity in the means employed, and an understanding of the one will clear the way to a comprehension of the other.

At first Messrs. Wheatstone and Cooke employed five magnetic needles, and either five or six wires, with a peculiar keyboard, on which were arranged the letters of the alphabet. After a time only one needle was employed, different letters being designated by the deflection of the needle to the right or to the left, one or more times, in either or both directions, the swinging of the needle being checked by small pins fixed on the dial, so that the motions were rendered precise and clear. Operators accustomed

to the work do not require the lettered dials for reading the movements of the needle, and some can even read off a message transmitted at the rate of 100 letters a minute. This, however, is a remarkable feat both of transmission and reading; and the ordinary rate at which messages are sent is about 24 words a minute.

The Morse system is very different. At the sending end is a voltaic battery, at the receiving end an electro-magnet, which, when the current passes, attracts an "armature," or piece of soft iron placed at the pole, by which, according to the duration of the current, dots or lines are marked with a steel point upon a moving slip of paper. At the sending end is an apparatus known as "the key," consisting of a small lever with a button at the end, on pressing which two platinum wires are brought into contact, and the shock is transmitted; but when the pressure is removed, a spring lifts the lever, separates the wires, and breaks the circuit. The paper on which the message is to be recorded, is carried between two rollers moved by clockwork. In one of these rollers is a groove, into which the steel point presses the paper. When successive blows are struck on the key at the sending end, closing and opening the circuit quickly, corresponding dots appear on the paper; but, if the key be pressed down for a longer or shorter time, keeping the circuit closed, a continuous line of any desired length may be produced on

the paper. Every letter of the English alphabet and every numeral has a sign ; and there are also marks of punctuation. We need not give the entire alphabet, the signs for the first five letters being sufficient to exemplify the system :—

A - — , B — - - - , C - - - , D — - - , E - ,
F - — - .

The word “Victoria” thus transmitted would appear on the slip of paper at the receiving end in this fashion :—

- - - — | - - | - - - | — | - - | - - - | - - | - —

We have inserted dividing lines between the letters for the sake of clearness, but they are not practically used. The skilled operator with the Morse instrument can read off the message as it arrives without looking at the marks on the paper, simply by listening to the “click” which is made every time the circuit is completed or broken, and we are told “practice has taught him to rely on the evidence of his ears with as much confidence as one less accustomed to the work would trust his eyes ;” that is, his cultivated ear enables him to estimate so correctly the length of the currents as indicated by the clicks that he knows what letters are being impressed on the paper.

TRANSMISSION OF SOUND.

The sensation of sound is the final effect of a closely considered series of mechanical actions which have their origin in some rapidly vibratory body, whence they are propagated progressively through solid liquid or gaseous bodies.

“If,” says Professor Dolbear, “I strike my pencil upon the table, I hear a snap that appears to the ear to be simultaneous with the stroke : if, however, I see a man upon a somewhat distant hill strike a tree with an axe, the sound does not reach me until some appreciable time has passed ; and it is noted, that, the farther away the place where a so-called sound originates, the longer time does it take to reach any listener. Hence sound has in air a certain velocity which has been very accurately measured, and found to be 1,093 feet per second when the temperature of the air is at the freezing point of water. As the temperature increases, the velocity of sound will increase a little more than one foot for every Fahrenheit degree ; so that at 60° the velocity is 1,125 feet per second. This is the velocity in air. In water the velocity is about four times greater, in steel sixteen times, in pine-wood about ten times.

“If a person stands at a distance of fifteen or twenty rods from a cannon that is fired, he will first see the

flash, then the cloud of smoke that rushes from the cannon's mouth, then the ground will be felt to tremble, and lastly the sound will reach his ear at the same time that a strong puff of air will be felt. This puff of air is the sound wave itself, travelling at the rate of eleven hundred feet or more per second. At the instant of explosion of the gunpowder, the air in front of the cannon is very much compressed ; and this compression at once begins to move outwards in every direction, so as to be a kind of a spherical shell of air constantly increasing in diameter ; and, whenever it reaches an ear, the sound is perceived. Whenever such a sound-wave strikes upon a solid surface, as upon a cliff or a building, it is turned back, and the reflected wave may be heard ; in which case we call it an echo. When a cannon is fired, we generally hear the sound repeated, so that it apparently lasts for a second or more ; but when, as in the first case, we hear the sound of a pencil struck upon the table, but a single short report is noticed, and this, as may be supposed, consists of a single wave of condensed air.

“ Imagine a tuning-fork that is made to vibrate. The two prongs beat the air in opposite directions at the same time. The vibration of one of the prongs is from *a* to *b* (Fig. 1). Look at the physical condition of the air in front of one of these prongs. As the latter strikes outwards, the air in front of it will be driven outwards, condensed ; and, on account of the elasticity

of the air, the condensation will at once start to travel outwards in every direction—a wave of denser air; but directly the prong recedes, beating the air back in the contrary direction, which will obviously rarefy the air on the first side (Fig. 2). The disturbance we call rarefaction moves in air with the same velocity as a condensation. We must therefore remember, that

FIG. 1.

FIG. 2.

just behind the wave of condensation is the wave of rarefaction, both travelling with the same velocity, and therefore always maintaining the same relative position to each other. Now, the fork vibrates a great many times in a second, and will consequently generate as many of these waves, all of them constituted alike, and having the same length; by length meaning the sum of the thicknesses of the condensa-

tion and the rarefaction. Suppose a fork to make one hundred vibrations per second : at the end of the second, the wave generated by the vibration at the beginning of the second would have travelled, say, eleven hundred feet ; and evenly distributed between the fork and the outer limit, would be ranged the intermediate waves occupying the whole distance : that is to say, in eleven hundred feet there would be one hundred sound-waves, each of them evidently being eleven feet long. If the fork made eleven hundred vibrations per second, each of these waves would be one foot long ; for sound-waves of all lengths travel in air with the same rapidity."

Sir Charles Wheatstone has shown by a beautiful experiment that even the most complex sounds may be transmitted as readily as through the air. In the lower room of a house, or in a lightly closed box lined with felt, he placed a musical-box. On the top of the musical-box rested the end of a long, light wooden rod, which reached to one of the rooms above, the rod being insulated from the floor of the room by india-rubber. No sound was perceived in the upper room until a violin, guitar, or other instrument with a sounding-board was placed on the top of the rod, when the sounds of the musical-box filled the upper room and appeared to emanate from the musical instrument on the rod. A very striking adaptation of this experiment has been exhibited at some of those institutions where scientific instruction is combined with

amusement. On a platform was placed several musical instruments, but no players. Suddenly it appeared as if invisible performers were uniting in a concert, each instrument seemingly taking its part. The explanation was, that other instruments in a lower part of the building were played on, the vibrations of sound being conveyed by thin wooden rods to the corresponding instruments above.

About the year 1848, an exhibition of this kind took place before the Queen, at the Polytechnic Institution, Regent Street, Mr. Wheatstone bringing, by means of wooden rods, the music of a band from a distant part of the building into the room where her Majesty was. An amusing anecdote regarding this invention is related by Mr. Chappell. An eminent foreign performer on the violoncello came to England, bringing a letter of introduction to Wheatstone. He left the letter at the house, and appointed to call at a particular hour on the following day. Wheatstone was at home to receive him, and, thinking to surprise and amuse his visitor, hung a violoncello on the wall of the passage, having a rod behind it to connect it with another, which was to be played from within when he entered the hall. The guest turned in every direction to find whence the sounds came, and, at last, approaching the violoncello hanging on the wall, and, having satisfied himself that they proceeded from it, although there was neither hand nor bow to play upon it, he rushed out

of the house in affright, and would never enter it again ! Wheatstone also made the invention a source of domestic amusement, by fitting up a lyre in a small boudoir, connecting it by a rod through the ceiling with a pianoforte in the room above, and his daughter was to amuse friends by playing unseen on the piano by means of the apparatus below.

We have heard many wonderful accounts of guitars and banjos giving out lively music in locked cabinets, when it seemed impossible that any human hands could touch the strings ; and we are tempted to ask if the slender wooden legs of the cabinet had any connection with guitars and banjos in a floor beneath. Visitors to spiritualistic "mediums" are often astonished by hearing tunes played on a piano at which no visible performer is seated ; and a closed and locked instrument will suddenly become amazingly musical. Wheatstone's rod arrangement is no secret, and the real performer may, perhaps, be a very tangible piece of humanity, comfortably seated in a room below. A familiar instance of the transmission of sounds through a solid medium is afforded by the fact that if a person places his ear against one end of a large log of timber he can distinctly hear even the scratch of a pin at the other end, so sensitive to vibrations of sound is even the solid oak or elm.

Eton boys have long been acquainted with a means of communication between the dormitories, using a tightly-stretched string, which, to a certain extent,

answers the same purpose as a wooden rod. At each end of the string is tied a ring, about two inches in diameter, covered with bladder taken from empty marmalade pots. The string is stretched between two dormitories, and the youthful experimentalist speaks with the bladder close to his mouth, the string conveying the vibrations to the other bladder, where they are distinctly heard. A toy telephone constructed in this manner has been sold in the London toy-shops. Speaking machines have been exhibited, in which words apparently proceeded from the mouth of a figure, and there was a display of apparatus, worked by keys, somewhat resembling those of a piano. The question suggests itself, was the apparatus shown a "dummy," and was there really a speaker in another room, the rather indistinct and muffled tones of the "speaking machine" being due to the stretched membrane?

The air transmits sounds, of course, or we should never hear them; and it is well ascertained that sonorous vibrations will pass through water.

"Pitch," that quality of sound by which we distinguish the position of sounds on the musical scale, depends upon the number of the vibrations in a given time. The greater the number, the "higher" the note; the less, the "lower". The smallest number of vibrations which produce a continued sound is 40 in a second; but the average human ear can recognize sounds caused by about 40,000 vibrations in a second,

consequently of great acuteness. The musical note C, "below the line" of the treble clef, has theoretically 256 vibrations to the second; but our musical readers are well aware that "the pitch" is a subject on which very eminent musicians are not quite agreed, and has been the cause of much discussion, in which we shall not take part, as we are not writing a musical treatise; and for the same reason we need not dwell upon the exact relations or the number of vibrations which musical sounds bear to each other. But one peculiarity of sound must be noticed because of its especial reference to the possibility of recognising particular voices transmitted to a distance, and that peculiarity is "timbre," a word which has been much used in connection with discussions on this subject. In French the word means "bell," and in reference to the voice, means the "ring;" that special character by which we distinguish between two or more sounds having the same pitch. The ear at once distinguishes a difference between the same musical note produced by a flute, a violin, a clarinet, or a pianoforte; or between the voices of two singers, singing with the most careful accuracy the same music.

DISCOVERY OF THE TELEPHONE.

It being established by the investigations we have briefly described, and the results so triumphantly attained, that electric currents can be transmitted through wires to a practically unlimited distance without loss of power; that by electro-magnetism the currents may be made intermittent, so as to produce intelligible signals; and it being also established that sonorous vibrations can be transmitted through solid, liquid, or gaseous mediums, it became a question of great interest to scientific inquirers whether, by the aid of electro-magnetism, not only the vibrations of sound might be communicated, but also vibrations of pitch, and even articulate utterances.

While Wheatstone was engaged in perfecting his telegraphic invention, he had his attention seriously directed to the subject of transmission of sounds by wire, and knowing already the transmissibility of delicate musical sounds through rods (see page 28), it was easy for him to convey the tick of a clock through wire to his electro-magnetic clock. This he described as "an instrument which shall indicate the time and beat dead seconds *audibly*." This clock was exhibited to the Royal Society on the 26th November, 1840, and Mr. William Chappell, the well-known writer on

musical subjects, who was present on the occasion, says in a letter to the *Athenæum*.—

“Having seen a huge coil of wire in the well of the staircase, on entering Somerset House that evening, I went up to the library and tea-room of the Royal Society to learn what had been going on. Wheatstone pointed out to me a clock-face in the room. It was perfectly transparent and had hands; but every one could see that there were no works within it, yet the hands moved, and the clock-face ticked most audibly. He took me out on the staircase to hear the perfect simultaneity and the equal force of the tick with that of the clock in the hall below. It was the sound of that clock which had been conveyed through a coil of wire of some miles in length to the clock-face in the library on high. The sound above and the sound below were in perfect unison, and of absolute equality in force as well as of pitch. As this was the first electric clock, so *Wheatstone was the first to employ the electric wire for the transmission of sounds*, as well as to transmit them by rods, without the use of electricity.”

In fact, Professor Wheatstone constructed a Telephone, which could reproduce the tick of a clock at the end of several miles of wire; but that was a simple result, although it went a long way towards establishing the principle.

About 1852, Professor Reis of Friedrichsdorf (near Hombourg, in Germany), made some experi-

ments, but without producing very satisfactory results ; but, in 1860, succeeded in constructing an apparatus, the distinctive feature of which was a stretched membrane vibrating to a particular pitch or note. A contact piece was adjusted near the membrane, and a series of rapid contacts sent a series of clicks along an electric wire to an electro-magnetic receiver at the other end ; but only one note or musical sound could be conveyed.

The first published notice of Reis's telephone appeared in a daily paper of Frankfort-on-the-Maine. Referring to Reis's instrument, Professor Barrett said, in a lecture recently delivered :—"The first Telephone was of a most primitive nature. The originating instrument was a bung of a beer barrel hollowed out, and the cone formed in this way was closed with the skin of a German sausage, which did service as a membrane. To this was fixed with a drop of sealing-wax a little strip of platinum, representing the hammer of the ear, and which 'made' or 'broke' the electric circuit, precisely as in the instruments of a later date. The receiving instrument was a knitting needle surrounded with a coil of wire and placed on a violin to serve as a sounding-board."

To Reis, then, is due the first conception of causing the voice to vibrate a membrane and through it to "make" and "break" an electric circuit. He thus caused the vocal "shiver" to be converted into an electric "shiver." Professor Barrett illustrated the

vocal "shiver" in a way that any one can reproduce. A wooden box had a sheet of writing paper stretched across the top, and into one side of the box was placed a piece of metal tube. Coloured sand was sprinkled on the paper, and then the voice and various instruments were one after another sounded into the tube. The patterns into which the sand was thrown were seen to change with the different notes sounded. No simpler method, no method more easily reproduced at home has probably ever been shown before. Reis's electric "shiver" at the further end, responsive to the vocal "shiver," was due to a principle that the knitting needle was made a magnet by each passage of electricity, and the magnetisation and demagnetisation of a bar of iron is accompanied by a sound. It is true that this instrument makes only a succession of clicking sounds, but here was the germ of the use of the vibrating membrane for receiving sound and converting the motion into electric "shocks" that could be transmitted to a distance.

About two years afterwards, Reis succeeded so far that, by his apparatus, a song could be heard and the tune recognised, but the words could not be distinguished.

Nearly five years ago, Mr. Thomas A. Edison, a telegraphic engineer of Manlowe Park, New Jersey, United States—to whose labours we shall presently refer in connexion with an even more marvellous application of telephonic science—attempted to con-

struct a Telephone, but we believe with but imperfect success. He was familiar with the fact that signals are recorded by sending an electric current through prepared paper saturated with a chemical agent, which changes its colour wherever the current touches it, the paper being moved on equally, and a pen or stylus, resting upon it, conveying the impulse received from the electric wire ; and he tried to devise an arrangement for producing sound as well as discolouration, something for the ear to hear as well as something else for the eye to see.

More recently, Mr. Elisha Gray of Chicago, considerably improved on the instrument of Reis, as will be shown further on in a notice of the results obtained ; and Mr. Paul Lacour of Copenhagen, also arranged an apparatus which transmitted finer sounds than were afforded by the instrument of Mr. Gray.

But the greatest success has been achieved by Professor Alexander Graham Bell, son of Mr. Alexander Melville Bell, a well-known teacher of elocution, inventor of the system of "visible speech." Father and son have long been engaged in perfecting the method of teaching the dumb to speak, with the most amazing results ; and the younger teacher, his mind dwelling on the possibility of obtaining more perfect telephonic transmission than Reis and the others had been successful in producing, and not undervaluing but bravely encountering the difficul-

ties of the task, said : "If I can make a deaf mute talk, so can I make iron talk."

We are indebted to the report of a lecture delivered by Professor Bell, before the Society of Telegraphic Engineers, on the 31st of October, 1877, for an account of his earlier efforts in the direction to which his thoughts were turned :—

"Many of those present may recollect the invention by my father of a means of representing, in a wonderfully accurate manner, the positions of the vocal organs in forming sounds. Together we carried on quite a number of experiments, seeking to discover the correct mechanism of English and foreign elements of speech, and I remember especially an investigation in which we were engaged concerning the musical relations of vowel sounds. When vowel sounds are whispered, each vowel seems to possess a particular pitch of its own, and by whispering certain vowels in succession a musical scale can be distinctly perceived. Our aim was to determine the natural pitch of each vowel ; but unexpected difficulties made their appearance, for many of the vowels seemed to possess a double pitch—one due, probably, to the resonance of the air in the mouth, and the other to the resonance of the air contained in the cavity behind the tongue, comprehending the pharynx and larynx. I hit upon an expedient for determining the pitch which at that time I thought to be original with myself. It consisted in vibrating a tuning-fork in

front of the mouth while the positions of the vocal organs for the various vowel sounds were silently taken. It was found that each vowel position caused the reinforcement of some particular fork or forks. I wrote an account of these researches to Mr. Alex. J. Ellis of London. In reply he informed me that the experiments related had already been performed by Helmholtz, and in a much more perfect manner than I had done. Indeed, he said that Helmholtz had not only analysed the vowel sounds into their constituent musical elements, but had actually performed the synthesis of them. He had succeeded in producing, artificially, certain of the vowel sounds by causing tuning-forks of different pitch to vibrate simultaneously by means of an electric current. . . .

While reflecting upon the possibilities of the production of sound by electrical means, it struck me that the principle of vibrating a tuning-fork by the intermittent attraction of an electro-magnet might be applied to the electrical production of music. I imagined to myself a series of tuning-forks of different pitches, arranged to vibrate automatically in the manner shown by Helmholtz, each fork interrupting at every vibration a voltaic current; and the thought occurred, 'Why should not the depression of a key like that of the piano direct the interrupted current from any one of these forks, through a telegraph wire, to a series of electro-magnets operating the strings of a piano or other musical instrument, in which case a

person might play the tuning-fork piano in one place and the music be audible from the electro-magnetic piano in a distant city ? ' The more I reflected upon this arrangement the more feasible did it seem to me ; indeed, I saw no reason why the depression of a number of keys at the tuning-fork end of the circuit should not be followed by the audible production of a full chord from the piano in the distant city, each tuning-fork affecting at the receiving end that string of the piano with which it was in unison. At this time the interest which I felt in electricity led me to study the various systems of telegraphy in use in this country and in America. I was much struck with the simplicity of the Morse alphabet, and with the fact that it could be read by sound. Instead of having the dots and dashes recorded upon paper, the operators were in the habit of observing the duration of the click of the instruments, and in this way were enabled to distinguish by ear the various signals. It struck me that in a similar manner the duration of a musical note might be made to represent the dot or dash of the telegraph code, so that a person might operate one of the keys of the tuning-fork piano referred to above, and the duration of the sound proceeding from the corresponding string of the distant piano be observed by an operator stationed there. It seemed to me that in this way a number of distinct telegraph messages might be sent simultaneously from the tuning-fork piano to the other end of the

circuit, by operators each manipulating a different key of the instrument. These messages would be read by operators stationed at the distant piano, each receiving operator listening for signals of a certain definite pitch, and ignoring all others. In this way could be accomplished the simultaneous transmission of a number of telegraphic messages along a single wire, the number being limited only by the delicacy of the listener's ear. The idea of increasing the carrying power of the telegraph wire in this way took complete possession of my mind, and it was this practical end that I had in view when I commenced my researches in electric telephony."

In the course of the investigation, it occurred to him that if he could vibrate a piece of iron—to give to that piece of iron not the vibration of a musical tone, but the resultant vibration of a vowel sound—an undulatory current would be produced directly, not indirectly, which would correspond to the motion of the air in the production of a sound. The difficulty was, however, how to vibrate a piece of iron in the way required. Mr. Bell had been examining and experimenting with an instrument known as the Phonautograph, which produced a diagram of curves in accordance with the vowel sound. It consisted of a cone into which a person spoke, which condensed the air from the voice; and there was at the small end of the cone a stretched membrane, which vibrated when a sound was produced, and, in the

course of its vibration, it controlled the movement of a long style of wood, about 1 ft. in length, and these curves were drawn by the style upon a surface of smoked glass, which was dragged rapidly along. Mr. Bell says (in a lecture delivered before the Society of Arts on the 28th November, 1877): "I attempted to construct a phonautograph, modelled as nearly as possible on the mechanism of the human ear, but upon going to a friend in Boston, Dr. Clarence J. Blake, an aurist, he suggested the novel idea of using the human ear itself as a phonautograph, and this apparatus we constructed together. It is a human ear. The interior mechanism is exposed, and to a part of it is attached a long style of hay. Upon moistening the membrane and the little bones with a mixture of glycerine and water, the mobility of the parts was restored, and on speaking into the external artificial ear, a vibration was observed, and after many experiments we were able to obtain tracings of the vibration on a sheet of smoked glass drawn rapidly along. The apparatus gave me the clue to the present form of Telephone. What I wanted was an apparatus that should be able to move a piece of iron, in the way that a particle of air is moved by the voice. It struck me in the course of these experiments that there was great disproportion between the tissue of the membranes and the bones that were moved by the membranes, and that if such a thin and delicate membrane could vibrate a mass of bone, so disproportionate in

size and weight, perhaps a membrane might be able to vibrate a piece of iron in the way required. I therefore constructed a second form of articulating Telephone, founded on the first apparatus by which I was, at the time of these experiments, producing undulatory electricity for the purpose of producing musical tones. It was attached to one pole of an electro-magnet, and magnetised by means of a battery current. A current being passed through the coils of the magnet this piece of iron became magnetic, and a rod attached to one pole would of course become magnetic also, as if attached to a permanent magnet, so that, on vibrating this rod in any way whatever, the battery current was put in operation, and the corresponding rod at the other end thrown into vibration. I, therefore, took this apparatus, and instead of clamping the rod firmly, it was attached loosely to one extremity of the magnet, and the other end was attached to a stretched membrane of goldbeater's skin ; and the same at the other end. The idea was that on speaking to this membrane, it would be thrown into vibration, and cause the vibration of the piece of iron, that in fact the iron would follow the motion of the membrane, that is, of the particles of air ; it would, therefore, induce an undulatory current of electricity the intensity of which would vary with the motion, and at the other end the intensity of the magnetic attraction would vary in a similar way ; so that the piece of iron at the other end, being attracted and

repelled in a varying manner, would be thrown into vibration, copying the motion of the first, and it in turn would cause the motion of a second stretched membrane, which would move the air in the neighbourhood, and we should thus have a sound produced. The idea was, that not only would the two pieces of iron vibrate together, but the form of the vibration would be the same, so that on speaking in the neighbourhood of one membrane we should have a fac-simile of the sound produced at the other end. The apparatus was constructed, but the results were rather unsatisfactory. My friend, Mr. Thomas Watson, who assisted me, however, asserted that he could hear a very faint sound proceed from the second membrane when I spoke in the neighbourhood of the first. Encouraged by this fact I varied the apparatus in a number of ways, and eventually produced three distinct forms of apparatus, which were exhibited at the Centennial Exhibition. I came to the conclusion that this piece of iron was probably rather too heavy to be set in vibration by the membrane, and I therefore made it as light as possible ; in fact, I took a piece of steel spring, only about the size of the pole of the electro-magnet itself, and glued it to the centre of the membrane. Upon constructing two of these instruments, there was no mistake at all that articulate speech was produced ; but it was of a very imperfect nature. When a person spoke or sung into one of these instruments, you could distinctly

hear the tones of the speaker's voice at the other end, and could recognise that there was articulation there, and when you knew the sentence that was uttered, you could recognise the articulation, and it seemed strange that you could not understand what it was at first. The vowel sounds seemed to be copied very fairly, but the consonant sounds were entirely alike."

Nothing discouraged by the imperfections which attended his first attempts, Professor Bell persevered, and in 1875 was enabled to send a musical message through a two-mile wire. He secured his invention by patent, and in the autumn of 1876 gave his first public exhibition of the system.

We will now return to the other experimenters in the same field. The great Centennial Exhibition was held at Philadelphia in the autumn of 1876, and of all the wonders of ingenuity and art there collected, none excited greater attention than the telephone. Mr. Bell's was exhibited, and so also was the apparatus invented by Professor Reis, already mentioned. We append a brief description, with illustrations of the latter instrument. No. 1 is the apparatus of transmission, and No. 2 the receiving instrument. At the station where a tune is played, a large tube, connected with a box, receives the vibrations of air produced by the musical instrument. The box serves to receive and reinforce the sound. On its upper side is stretched a membrane, which

vibrates in unison with the concussions it receives. The problem is to transform the vibrations of this membrane into musical cadences by means of an

REIS'S TELEPHONE (Fig. 1)

REIS'S TELEPHONE (Fig. 2).

electric current. The current is introduced and conducted by a copper leaf to a platinum disc. Every time the membrane swells up, the platinum pointer is

touched, and the connection established; it is disconnected when the membrane returns to repose. Here we have the making and breaking of a current by means of the vibration or waves of sound. The box is connected by means of telegraph-wire with the receiving instrument, which may be many miles distant. This latter is composed of an iron rod, about the size of an ordinary knitting-needle, wound around with insulated copper wire, one end of which is connected with the air-line, and the other with the earth, to complete the circuit. Not only is the time indicated, but also the note; the two elements which compose the melody—the heights of the sound and the interval between the notes—are automatically reproduced without the possibility of error. To complete the description of the instrument, it is necessary to add that in fig. 1 are a key and an electro-magnet, the usual arrangement of the Morse system to establish correspondence between the two stations. There must be a receiving instrument not indicated in the illustration. This extra apparatus can be dispensed with, as the telephone itself can be made to serve for purposes of communication. To give the telephone its highest value, it is necessary to study the form to be given to the box, and also to add to the agreeable sound of the receiving instrument by introducing several iron rods in the bobbin. The instrument of M. Reis differed essentially from the Telephone of Mr. Graham Bell, and is by no means so

perfect, but it is interesting as having been one of the pioneers in this branch of research.

The instrument sent by Mr. Bell to the same Centennial Exhibition was described in the official report signed by Sir William Thomson and others:—

“Mr. Alexander Graham Bell exhibits an apparatus by which he has achieved a result of transcendent scientific interest—a transmission of spoken words by electric currents through a telegraph wire. To obtain this result, Mr. Bell perceived that he must produce a variation of strength of current as nearly as may be a exact proportion to the velocity of a particle of air moved by the sound; and he invented a method of doing so—a piece of iron attached to a membrane, and then moved to and fro in the neighbourhood of an electro-magnet—which proved perfectly successful. The battery and wire of this electro-magnet are in circuit with the telegraph wire and the wire of another electro-magnet at the receiving station. The second electro-magnet has a solid bar of iron for core, which is connected at one end by a thick disc of iron to an iron tube surrounding the coil and bar. The free circular end of the tube constitutes one pole of the electro-magnet, and the adjacent free end of the bar core the other. A thin, circular iron disc held pressed against the end of the tube by the electro-magnetic attraction, and free to vibrate through a very small space without touching the central pole, constitutes the sounder by which the

electric effect is reconverted into sound. With my ear pressed against the disc, I heard it speak distinctly several sentences. . . . I need scarcely say I was astonished and delighted. So were others, including some judges of our group, who witnessed the experiments, and verified with their own ears the electric transmission of speech. This, perhaps the greatest marvel hitherto achieved by the electric telegraph, has been obtained by appliances of quite a homespun and rudimentary character. With somewhat more advanced plans and more powerful apparatus, we may confidently expect that Mr. Bell will give us the means of making voice and spoken words audible through the electric wire to an ear hundreds of miles distant."

The illustrations on pp. 50 and 51 show the Telephone exhibited by Mr. Bell, and described in the above report.

Mr. Elisha Gray appears to have achieved considerable success in the transmission of musical sounds. By the aid of his apparatus a performer played at Philadelphia to an audience at New York, 90 miles distant. The apparatus may be called a telephonic piano; it transmits the sounds of that instrument, but of no other. Public performances of this kind were given in the early months of 1877. On one evening the instrument was played at Chicago, and the music heard at Milwaukee, 87 miles distant. "The Last Rose of Summer,"

BELL'S FIRST TELEPHONE—THE TRANSMITTER.

The coil *a* is an electro-magnet, the soft iron rod in centre projects beyond the coil towards diaphragm, leaving a small space between them; *b*, diaphragm of gold-beaters' skin stretched over and fastened to the curled rim of movable brass collar, *c*. At the centre of diaphragm, on the side removed from the electro-magnet, is placed a bit of clock-spring about the size of thumb-nail; *d*, collar and short fixed tube of brass extending to *e*, which is the position of diaphragm; this latter can thus be tightened or loosened by means of the screws, *f*; *g*, mouthpiece to collect the volume of sound; *h*, battery; *i*, wire from battery to coil; *k*, telegraph wire from coil through binding screw, *l*; *m*, pillar holding magnet in place by means of smaller iron rod, which is fixed to one end of magnet.

“Yankee Doodle,” “The Sweet By-and-by,” and “Home, Sweet Home,” are named as the tunes thus played. On a second occasion the apparatus triumphed over a distance of no less than 284 miles, from Chicago to Detroit.

BELL'S FIRST TELEPHONE—THE RECEIVER.

n is an iron tube, inside which is a vertical bar electro-magnet, which attracts and causes to vibrate the thin armature, *o*.

A writer in *Chambers's Journal*, describing the results, tells us that “two instruments are required, a transmitter and a receiver. There is a keyboard of two octaves (available, therefore, only for simple melodies), a tuning bar, an electro-magnet, and an electric circuit. The play on the keys with the

fingers produces vibrations, thuds, molecular movements, in rhythmical succession ; these are transmitted by the electric wire to the receiving apparatus at the other end. This receiving apparatus is a large sounding-box, on which is mounted an electromagnet. The box intensifies the sounds by its sonorousness, through the medium of the slight touches which the magnetised iron gives to the box at every expansion or elongation which the electromagnetism gives it. Delicate experiments have shewn that there is a minute difference in the length of a bar of iron when magnetised and demagnetised, and Mr. Gray appears to have taken advantage of this property in causing his magnetised bar to give a succession of taps to the resonant box."

In July, 1877, Mr. Cromwell Varley, the well-known electrician, exhibited an apparatus at the Queen's Theatre, Long Acre ; and by means of a wire connected with the Canterbury Hall in the Westminster Bridge Road, tunes were transmitted from the one building to the other. A prominent feature of this Telephone was a series of tuning-forks, one for each note.

CONSTRUCTION OF PROFESSOR BELL'S TELEPHONE.

The instrument now used by Professor Bell, and which is by far the most successful of any yet produced, does not differ materially in principle from that shown at the Centennial Exhibition, and already described. But some modifications have been made in the direction of simplicity. An attentive reader of the extracts we have given from the lectures of Mr. Bell, and our brief summary of the leading principles of electro-magnetism and transmission of sound, will have no difficulty in understanding the construction and making of the telephone now in general use. But it may be convenient to present in a general manner the leading principles of the apparatus, before entering on a detailed description; and we avail ourselves of an excellent epitome of the subject given in a recent article in *Chambers's Journal*:—

“We must first comprehend the mode in which the sonorous transmission through the wire is brought about; for this it is which really constitutes the principle of the telephone. Ordinary telegraphic coils of insulated wire are applied to the poles of a powerful compound permanent magnet; and in front of these is a thin vibrating diaphragm or membrane,

with a metallic contact-piece cemented to it. A mouth-piece or trumpet mouth, fitted to collect and intensify waves of sound, is placed near the other surface of the diaphragm. It is known that the motion of steel or iron in front of the poles of a magnet creates a disturbance of electricity in coils surrounding those poles; and the duration of this current will coincide with the vibratory motion of the steel or iron. When, therefore, the human voice (or any other suitable sound) impinges through the tube against the diaphragm, the diaphragm itself begins to vibrate, and the contact-piece awakens (so to speak) electrical action in the coils of wire surrounding the poles of the magnet; not a current, but a series of undulations, something like those produced by the voice in the air around us. The undulations in the coil produce a current in the ordinary telegraph wire with which it is placed in connection. A similar apparatus at the other end is hereby set in action, but in reverse order; that is, the wire affects another coil, the coil another diaphragm, and the diaphragm another tube, in which the sounds are reproduced in audible vibrations."

In the earlier experiments by Professor Bell, he employed galvanic batteries to produce the current, but afterwards dispensed with them, and employed permanent magnets, the electric current being induced not by electro-magnetism, but by magneto-electricity, described at page 19.

The popular impression has been, concerning the telephone, that the *sound* was in some way conveyed over the wire, such is very far from being the case. The fact is, it is a beautiful example of the convertibility of forces from one form to another. There is first the initial vibratory mechanical motion of the air, which is imparted to the membrane carrying the iron. This motion is converted into electricity in the coil of wire surrounding the electro-magnet, and at the receiving end is first effective as magnetism, which is again converted into vibratory motion of the iron armature, which motion is imparted to the air, and so becomes again a sound-wave in air like the original one.

The accompanying diagrams may be referred to in further explanation of the construction of the instrument:—

It will be seen that Bell's Telephone consists of a cylindrical magnet, about five inches long and three-eighths of an inch in diameter, encircled at one extremity by a short bobbin of wood or ebonite, on which is wound a quantity of very fine insulated copper wire. The magnet and coil are contained in a wooden cylindrical case, and the two ends of the coil are soldered to thicker pieces of copper wire, which traverse the wooden envelope from one end to the other, and terminate in the binding screws at its extremity. Immediately in front of the magnet is a thin circular iron plate, which is kept in its place by

being jammed between the main portion of the wooden case and a wooden cap, in which is the opening

BELL'S TELEPHONE, NOW IN GENERAL USE.

This illustration represents the external appearance of the Telephone. The length is about seven or eight inches, and it is a receiver as well as transmitter.

for the mouth-piece (in the case of the receiving instrument, to be applied to the ear like an ear

trumpet). These two parts are screwed together, and the latter is cut away at the centre, so as to expose a

BELL'S TELEPHONE.—Section.

a, bobbin of coil wire round end of magnet; *b*, diaphragm of soft iron; *c*, mouthpiece; *d*, permanent magnet; *e*, wires, conducting from coil to binding screws; *f*, the two wires are at the end insulated and bound together in one strand for convenience of use; *g*, adjusting screw holding magnet.

portion of the iron plate about half an inch in diameter. The best thickness of the iron plate is

that of the ferrotype plate used by photographers, which is almost the thinnest procurable, and thin tin-plate is also available. The plate is cut into a disc, about two inches in diameter (in the instruments in ordinary use, but may be much larger), and is placed as near as possible to the extremity of the

USING THE TELEPHONE.

steel magnet without touching it ; the effect of this position being that, while the induced magnetism of the plate is considerable, it is susceptible to very rapid changes, owing to the freedom with which the plate can vibrate.

The dimensions given are those of the instrument generally used, and are found to be convenient ; but

a good working telephone may be made sufficiently small to be carried—of course excepting the connecting wires—in the waistcoat pocket, a magnet only an inch and a half long, producing good results.

There is no difference between the transmitting and receiving telephone, each instrument serving for both purposes. But it will be found convenient to have two on the circuit at each station, so as to avoid the inconvenience of shifting the instrument backwards and forwards between the ear and the mouth. The person taking part in the telephonic conversation can then hold one permanently to his ear, while he talks with the other, as shown in the illustration on the preceding page.

The illustration on the next page represents a long-distance telephone for office use, being also a transmitter as well as receiver.

DOLBEAR'S TELEPHONE.

Professor A. E. Dolbear, of Tuft's College, Massachusetts, United States, claims to have been the first inventor of the speaking Telephone in which magneto-electric currents are utilised for the transmission of

BELL'S LONG-DISTANCE TELEPHONE.

a, compound magnet; on to each pole of this is clamped a short round piece of bar iron, over which is a bobbin of coil wire, *b*; *c*, *d*, small space; *d*, diaphragm of thin sheet soft iron; *e*, speaking tube; *f*, telegraph wire; *g*, line to the earth. The magnet is held in its place by short cross pieces of wood. The whole is contained in mahogany case to fit in recess of wall, or elsewhere.

speech, and other kinds of sounds. We express no opinion as to the justice of his claim, but quote his description of a telephone which he has constructed :—

“ My first speaking-telephone consisted of a magnet made out of half-inch round steel bent into a U form, having the poles about two inches apart. Over these were slipped two bobbins taken from an old telegraph register, and were already fitted to a half-inch core. These bobbins, two inches and a half long, were wound with cotton-covered copper wire, No. 23, each bobbin containing about 150 feet. This magnet, with the bobbins slipped upon its poles, was made fast to a post two or three inches high. The steel was made as strongly magnetic as was possible, and would hold up three or four times its own weight. In front of the poles, a sheet of thin steel, one-fiftieth of an inch thick, was made fast to an upright board having a hole cut through it three and a half inches in diameter. The plate was screwed tightly to this board, so as to cover the hole ; and the middle of the hole was at the same height as the two poles of the magnet. The wires from the two bobbins were connected, as if to make an electro-magnet ; while the two free terminals were to be connected with the line-wires. Of course there were two of these instruments, both alike ; and talking and singing were reproduced with these.”

DIRECTIONS FOR MAKING A TELEPHONE ON DOLBEAR'S PRINCIPLE.

Professor Dolbear says :—"The following directions will enable any one to construct a speaking-telephone with which good results may be obtained. The specifications will be for only one instrument ; though of course two instruments made alike will be necessary for any purposes of speaking or other signals. Procure three common horseshoe magnets about six inches long, all of the same size. They should be strong enough to hold up several times their own weight each. Next, have turned out of good hard wood—such as maple or box-wood—two spools not over half an inch long and an inch and a half broad, the sides cut square both inside and out, a hole the third of an inch in diameter is to be made through the spool. Into this hole is to be fitted a short rod of soft iron about an inch long, which should be a little rounded at the outer end. The bobbins may be wound with as much insulated copper wire as they will hold. The wire may be from the one-fortieth to the one-fiftieth of an inch in diameter, as is most convenient to obtain, the latter size being preferable. The resistance of such bobbins will probably be from two to three ohms each. The soft iron core must project backwards far enough to

be clamped between the two outer magnets, while the inner one is drawn back. When the bobbins are in their places, and are clamped between the upper and lower magnets, they will stand as shown in Fig. 1,

DOLBEAR'S TELEPHONE (Fig. 1).

where the view is from above; the magnets being buttoned down to the block they rest on (see Fig. 2), which at the same time holds the soft iron rods with the bobbins upon them. The wires on these coils must be connected in the same way they would be in order to make opposite poles of their outer ends, if a current of electricity were to be sent through the coils. An upright board B (Fig. 2) six or seven inches square, having a round hole four inches in diameter cut out from the middle of it, must be fixed near the end of the baseboard; and over this hole is to be screwed *tightly* a piece of thin sheet iron or steel; it

may be from the one-twentieth to the one-fiftieth of an inch in thickness. It does not seem to make much difference about the thickness of this plate. I have generally got the best results from a plate one-fiftieth of an inch thick. The upright board carrying this plate must be very rigid, otherwise the plate will be kept tight to the magnets all the time; and one of the conditions of success in working is, that this

DOLBEAR'S TELEPHONE (Fig. 2).

plate shall be as close as possible to the magnet ends, but not to touch: therefore fix the board tight, and adjust the magnets by means of the button shown on top of them in the perspective figure.

The sounds to be transmitted, of whatever sort they may be, are to be made on the side P, Fig. 1; and likewise, when the instrument is used as a receiver, the ear is to be applied at the same place. A tube

about two inches in diameter may be made fast to the front of the board, in a line with the centre of the plate ; this will aid somewhat in hearing. When two or three persons are to sing, it will be best to have each one supplied with a tube to sing through ; one end of the tube to be placed close to the front of the plate. The sound of musical instruments, such as the flute and the cornet, will be reproduced much louder if the front of such instrument be allowed to rest upon the rim of the hole in the board, just in front of the plate."

PROFESSOR BARRETT'S CHEAP TELEPHONE.

At a lecture recently delivered, Professor Barrett showed "how to make a telephone at the cost of a few pence which is sold for £25." A tooth-powder wooden box has a hole cut through lid and bottom, a disc of tinned iron is fastened between them, a small straight bar magnet is put through a silk or small cotton reel and fixed near the disc, and round the reel is wound some wires. This is the "originator,"

and the "receiver" is similar. Some trials will be needed to adjust the exact distances, but the wire may extend from "originator" to "receiver" for some hundred yards.

POWER OF THE TELEPHONE.

Telegraphists test the carrying power of a current by employing a means of "resistance" equivalent to a telegraph line of stated length. This artificial resistance is nicely graduated, and the unit of resistance is termed an "ohm," from the name of Ohm, the German electrician who suggested the method. One hundred ohms is about equivalent to seven miles. Professor Bell says that he experienced no difficulty in his laboratory experiments, in conversing through a resistance of 60,000 ohms (more than 4,200 miles). The greatest length of real telegraph line through which he has attempted to converse has been about 250 miles. On one occasion the current passed through the bodies of sixteen persons who stood hand in hand; and very distinct sounds have been transmitted when a considerable mass of iron has been employed, and

further, when the iron was glued to a piece of wood an inch thick, and then interposed between it and the magnet, the action still continued, and a voice was heard at the distance of three miles. There is a marked difference in the manner in which letters are reproduced by the Telephone. Vowels are more acceptable than consonants, and, as a rule, those letters are best transmitted which involve opening the mouth widely in the utterance. High sounds appear to be produced more fully than low ones.

Mr. B. N. Warwick, a correspondent of the *English Mechanic*, describes some very interesting experiments he has made with telephones, testing the power of transmitting sound. He says :—

“The first magnets were about the size usually now employed, $\frac{1}{2}$ in. in diameter, and about eight times as long. Ferrotypes plates were first used, but these are by no means necessary. Removing these plates, I tried necessarily a number of substances ; first—thin tin-plate answered perfectly, both for sending and receiving. Sheet iron, about 1-50 in. thick, does not act so well, but all that is said is perfectly understood. While experimenting with these the plates were merely laid on the top of the instrument without being fixed in any way : the topmost wood part with the conical cavity was also discarded, as both transmitting and receiving went on equally well without it. This part of the instrument seems superfluous, as the sound, when the bare plate is

pressed flat against the ear, seems louder from the greater proximity. Now, iron plates do not appear to be absolutely necessary, although iron acts better than anything ; yet diamagnetic substances act very well. Desiring my assistant, who was some distance off and beyond reach by direct sound in any way, to continue counting for some time, I removed the iron plate and laid across the instrument a broad bar of iron $\frac{1}{4}$ in. thick. Placing my ear against it I heard every number distinctly, but somewhat enfeebled. A square piece of brass 3-8 in. was placed in position ; the sound, although distinct, was not so strong as the last. Next, thick pieces of lead, zinc, and steel were tried. The steel acted about the same as the thick iron, and as in the other cases every word spoken was feebly but distinctly heard. Now, some of these are diamagnetic metals, and yet the action goes on. Non-metallic substances were now tried—first a piece of window glass ; this acted very well indeed. With wood—a piece of matchbox—the action was feeble, but on placing other pieces of gradually increasing thickness the sound gradually increased, and with a rough piece of wood $1\frac{1}{2}$ in. thick the sound was perfectly distinct. I next placed an empty wood-box in position ; this acted very well. A square piece of cork $\frac{1}{2}$ in. thick acted, but rather feebly. A block of Turkey stone 2 in. thick was placed upon the instrument, and with this against the ear the speaker could be followed easily. I now tried

without anything at all intervening, and placed my ear close on the magnet and coil, and now, most curious of all, without any plate to vibrate, I could hear feebly, and by listening attentively I could understand all that was said. This was repeated many times. Mechanical transmission of sound was impossible, as many yards of wire lay coiled upon the ground, and yet, without anything (but air) intervening between my ear and the end of the magnet, I could understand what was said. Now, all these experiments were one way—the sounds were received. The sounds transmitted (or attempted) acted rather differently. A tuning fork, struck and placed on the thin iron plate or on the wood work, was heard clearly; for speech, the thin iron plates acted best. With the other substances, the stone, thick wood, glass, zinc, &c., the sound of the fork was heard by it either resting on them or by holding the vibrating prong over them. These thick substances did not answer for the sound of the voice. All these substances were now put aside, and the vibrating prong held directly over the pole of the magnet. This sound was clearly heard, although nothing intervened but air between the vibrating fork and the end of the magnet. The intensity of the sound was not nearly so great by resting the fork directly on the pole as when the vibrating fork was held over the end of the magnet. I next tried if my voice could be heard with this arrangement.

The result was rather doubtful, but I think some action must have taken place, for the fork was heard by merely vibrating in the vicinity of the pole, and the effect produced by the voice must have differed only in degree, and was too feeble to be heard at the other end. I have repeated and made quite sure of these results, and have succeeded in transmitting sound very distinctly without a plate over the pole, and have in return distinctly heard all that was said by placing my ear against the instrument—also without any plate whatever.”

Another correspondent of the *English Mechanic* supplies some hints which may be of service to amateur construction. He says:—“The numerous failures in making this instrument are due, in all probability, to two causes, (1) imperfect insulation of the coils, (2) imperfect metallic contact of the small or large wires with the connecting or binding screws. In making my Telephone, which is perfectly successful, I followed with the utmost care the directions and drawings given in the *Mechanic* a few weeks ago. Disappointment, however, awaited me, and every effort to make the instrument speak was unsuccessful until it occurred to me to borrow a medical magneto-electric machine, and place one of the coils in the circuit. The current was perfect through the first coil so tested, but the second refused to act, and on examining it I found that, owing to several kinks, and badly insulated joints in the wire, the

coil was useless. Having substituted another coil the instrument spoke at once. I have found that the cleaner the portion of the wire in contact with the connection, and the clearer the hole in the connection, the more perfect is the articulation. It is a good plan to bare about 2in. of the service wire, and having passed it through the hole in the connection to wind it once or twice round it. In this way sufficient contact is secured. The magnet should be withdrawn a little before the ferrotype plate is put on, as the attraction of the magnet has a tendency to draw the middle of the plate before it is properly gripped round the edges. The wires for my Telephones pass from my dining-room, through the kitchen, round the garden, up the back wall of the house into a second-floor room. I have used covered wire in the house, but outside I have employed common bell-wire, passing it once round iron staples over which I had previously slipped about an inch of small india-rubber tubing which answers perfectly as an insulator."

INTERESTING EXPERIMENTS.

THE TELEPHONE EXHIBITED TO THE QUEEN AT
OSBORNE HOUSE.

On Monday evening, the 14th of January, 1878, Professor Bell and Colonel Reynolds were presented to the Queen, at Osborne House, Isle of Wight, and exhibited the Telephone, being assisted by Mr. C. Wolleston. Professor Bell explained the mechanism of his invention, and then held telephonic communication with Osborne Cottage, the residence of Sir Thomas Biddulph. The apparatus there was under the management of Mr. F. C. Ormiston, who was the first to address the Royal party. Her Majesty conversed with Sir Thomas and Lady Biddulph, and later Miss Kate Field, who was at Osborne Cottage, sang "Kathleen Mavourneen," for which Her Majesty returned thanks telephonically through the Duke of Connaught. Miss Field afterwards sang Shakespeare's "Cuckoo Song" and "Comin' thro' the Rye," and delivered the epilogue to *As You Like It*, all of which were heard distinctly. The applause which followed came through the Telephone. The Princess Beatrice, the Hon. Mrs. Ponsonby, and others conversed with Osborne Cottage, sometimes through a circuit of one, three, and five persons. As the evening wore

on telephonic connection was established between Osborne House and Cowes, Southampton, and London. At Cowes, where Major Webber, of the Royal Engineers, superintended the line, a quartet of tonic-sol-fa singers sang several part songs, which produced an admirable effect, and the Duke of Connaught talked for several minutes with Major Webber. Attention was then turned to Southampton, where Mr. W. H. Preece, of the Post-office, talked as fluently with Professor Bell and Colonel Reynolds as though he were in the next room. A bugle in Southampton sounded the retreat with startling distinctness ; and, lastly, came the tones of an organ from London, in charge of Mr. Wilmot. Cheering and laughing in London were heard, the distance being 80 miles. The experiments lasted from half-past nine until nearly midnight. Her Majesty, the Princess Beatrice, the Duke of Connaught, and the entire Royal household evinced the greatest interest. On the following morning, Professor Bell made very successful experiments between Cowes, Osborne House, and Osborne Cottage, at which the Princess Beatrice, the Duke of Connaught, the Duke of Richmond, Lord John Manners, Lord Ripon, Lady Biddulph, Lady Cowell, Sir John Cowell, and others assisted.

The following correspondence has since passed between Sir Thomas Biddulph and Professor Bell :—

OSBORNE, *January 16th*, 1878.

"My Dear Sir,—I hope you are aware how much gratified and surprised the Queen was at the exhibition of the Telephone here on Monday evening. Her Majesty desires me to express her thanks to you, and the ladies and gentlemen who were associated with you on the occasion. The Queen would like, if there is no reason against it, to purchase the two instruments still here, with the wires attached. Perhaps you will be so kind as to let me know, and when the sum due shall be paid. With many thanks,

I am, my dear Sir,

Very faithfully yours,

THOS. BIDDULPH."

To this Professor Bell returned this answer :—

57, WEST CROMWELL ROAD, KENSINGTON.

January 18th.

"Dear Sir,—I feel highly honoured by the gratification expressed by Her Majesty, and by her desire to possess the Telephones. The instruments at present at Osborne are merely supplied for ordinary commercial purposes, and it will afford me much pleasure to be permitted to offer to the Queen a set of Telephones made expressly for Her Majesty's use.

Your obedient servant,

ALEXANDER GRAHAM BELL."

PARLIAMENTARY DEBATE REPORTED.

A portion of the debate in the House of Commons and of the Parliamentary Summary was transmitted by means of the Telephone, through the ordinary telegraphic wires from the gallery of the House of

Commons to the office of the *Daily News*, in Bouverie Street, Fleet Street, and published in that journal on Wednesday, the 23rd of January, 1878.

MESSAGES TO THE SHAH OF PERSIA.

We see it announced that the Persian Ambassador has sent several messages by Telephone to the Shah. The distance between London and Teheran (about 2,500 miles) is, we believe, the greatest distance yet achieved in actual communication.

At the conclusion of Professor Bell's lecture before the Society of Telegraph Engineers, he related the results of some remarkable experiments, results in some instances, quite unanticipated. He said:—

“Professor Peirce has observed the most curious sounds produced from a Telephone in connection with a telegraph-wire during the aurora borealis ; and I have just heard of a curious phenomenon lately observed by Dr. Channing. In the city of Providence, Rhode Island, there is an overhouse wire about one mile in extent with a Telephone at either end. On one occasion the sound of music and singing was faintly audible in one of the telephones. It seemed as if some one were practising vocal music with a pianoforte accompaniment. The natural supposition was that experiments were being made with the Telephone at the other end of the circuit, but upon in-

quiry this proved not to have been the case. Attention having thus been directed to the phenomenon, a watch was kept upon the instruments, and upon a subsequent occasion the same fact was observed at both ends of the line by Dr. Channing and his friends. It was proved that the sounds continued for about two hours, and usually commenced about the same time. A searching examination of the line disclosed nothing abnormal in its condition, and I am unable to give you any explanation of this curious phenomenon. Dr. Channing has, however, addressed a letter upon the subject to the editor of one of the Providence papers, giving the names of such songs as were recognised, with full details of the observations, in the hope that publicity may lead to the discovery of the performer, and thus afford a solution of the mystery.

“My friend Mr. Frederick A. Gower communicated to me a curious observation made by him regarding the slight earth connection required to establish a circuit for the Telephone, and together we carried on a series of experiments with rather startling results. We took a couple of Telephones and an insulated wire about 100 yards in length into a garden, and were enabled to carry on conversation with the greatest ease when we held in our hands what should have been the earth wire, so that the connection with the ground was formed at either end through our bodies, our feet being clothed with cotton socks and leather boots. The day was fine, and the grass upon which

we stood was seemingly perfectly dry. Upon standing upon a gravel walk the vocal sounds, though much diminished, were still perfectly intelligible, and the same result occurred when standing upon a brick wall one foot in height, but no sound was audible when one of us stood upon a block of freestone.

“One experiment which we made is so interesting that I must speak of it in detail. Mr. Gower made earth connection at his end of the line by standing upon a grass plot, whilst at the other end of the line I stood upon a wooden board. I requested Mr. Gower to sing a continuous musical note, and to my surprise the sound was very distinctly audible from the Telephone in my hand. Upon examining my feet I discovered that a single blade of grass was bent over the edge of the board, and that my foot touched it. The removal of this blade of grass was followed by the cessation of the sound from the Telephone, and I found that the moment I touched with the toe of my boot a blade of grass or the petal of a daisy the sound was again audible.

“I am informed by my friend Mr. Preece that conversation has been successfully carried on through a submarine cable, sixty miles in length, extending from Dartmouth to the Island of Guernsey, by means of hand Telephones.”

In February, 1877, a lecture was delivered on the subject of Telephony, by Professor Bell, at Salem, Massachusetts, and was audible word for word at

Boston. In order to show that the transmission is equally available in both directions, provided the proper apparatus is at both ends, the lecture from Salem to Boston was followed on the same evening by singing and speech-making from Boston to Salem.

At one of the experimental trials between Boston and Salem, a lady sang "The Last Rose of Summer," and was distinctly heard at the distant station; the sounds had about the same effect as if the listeners were at the rear of a concert-hall, say a hundred feet from the singer. The sounds of laughter and applause were similarly transmitted, with the proper rhythm and key or musical pitch. In instrumental music a violin could be distinguished from a violoncello; a test more delicate than would be supposed by many persons.

On another occasion, Professor Bell stationed himself in the Lyceum at Salem, Mr. T. A. Watson at Boston. An intermittent current, sent through the eighteen miles of telegraphic wire, produced in the telephone a horn-like sound. The Morse alphabet was then transmitted in musical sounds, audible throughout the lecture-hall. Then the sounds of an organ were made to act upon the apparatus, and these in like manner were transmitted; two or three tunes being distinctly heard in succession at Boston. Professor Bell then signalled to Mr. Watson to sing a song; this was done, and the words as well as the tune of the song heard. A speech was then made at

Boston in the simple words : “Ladies and gentlemen, it gives me great pleasure to be able to address you this evening, although I am in Boston and you in Salem.” This speech was heard distinctly in the Lyceum at Salem, and was followed by many questions and answers sent to and fro.

A correspondent of the *English Mechanic* says :—
“I have recently gathered a few curious matters in telephony. The engineer of the Submarine Company, at Dover, while experimenting by Bell’s Telephone through one of the channel cables, from England to France, distinctly heard the Morse symbols passing through the other cable. He inquired if they were sending a telegram by the other cable, and the answer was yes—thus showing a kind of duplex telephony. On another occasion, while this gentlemen was speaking into the Telephone at St. Margaret’s Bay, Dover, he could simultaneously hear voices at the French end of the cable. On Christmas Eve four children sang a carol over a Telephone ; listeners at the other end of the wire could distinguish the separate voices—the children did not keep time together nicely—which makes it more strange how the diaphragm of the instrument could vibrate for the four voices without causing a confused mass of hum, as might have been supposed. I should like the opinion of some talented readers why the voice of a speaker appears so very distant, as the diaphragm of the receiving instrument is so very close to the ear.”

The last sentence of the letter just quoted refers to a remarkable phenomenon which has been observed. A ventriloquial effect is produced, the sound appearing to proceed, not from the mouth of the instrument, but from some other place. The writer of a very interesting article in *Chambers's Journal* says:—"The voice, whether in speaking or singing, has a weird curious sound in the Telephone. It is in a measure ventriloquial in character; and with the Telephone held an inch or two from the ear, it has the effect as if some one were singing far off in the building, or the sound were coming up from a vaulted cellar or through a massive stone wall. . . . Every syllable, and every turn of melody of such a song as 'My Mother bids me bind my Hair,' sung by a lady at one end, or 'When the Heart of a Man,' sung at the other, could be distinctly heard, but with the effect before noticed, that the voice was muffled or shut in, as if the singer were in a cellar, while it was not always possible to say at once whether the voice was that of a man or a woman."

“TAPPING” THE TELEGRAPH WIRES.

While we are yet only at the beginning of our acquaintance with the capabilities of the Telephone, and scientific men are investigating how it may be employed so as to obtain from it the utmost measure of usefulness, it has been already discovered that, if deftly employed, it can be used as a medium for procuring revelations never intended to be intrusted to its keeping. It is able to steal the secrets of the telegraph. It is sufficient to cause a Telephone wire to run close by a telegraph wire for a comparatively moderate distance, in order to be able to hear through the Telephone the signs given at the other end by the telegraph apparatus. It would seem from this that anyone need only attach the wire of a Telephone to a telegraphic wire in order to “tap” it, and become possessed of all the secrets which are being conveyed along it. There is, however, one indispensable condition for gratifying such curiosity. The operator must possess so educated an ear that he can understand the telegraphic signs upon merely hearing them. Since telegraphic officials alone, and only very few even among them, can be presumed to have such finely-trained hearing, the danger suggested by this discovery does not, as yet, at least, seem to be very great; and besides, the process of tapping by

Telephone could not be carried out if the instrument in use were an A B C, or a single needle, or if the wire were being worked duplex, or with a fast speed Morse, for in these cases the sounds are too rapid or too indefinite to be read by ear. The danger is thus limited to ordinary "sounder" or Morse telegraphs ; but these still form the mainstay of every public system. The Morse system of "dots and lines" is explained at page 24.

Professor Bell says, in reference to this subject:—

"When a Telephone is placed in circuit with a telegraph line, the Telephone is found seemingly to emit sounds on its own account. The most extraordinary noises are often produced, the causes of which are at present very obscure. One class of sounds are produced by the inductive influence of neighbouring wires and by leakage from them, the signals of the Morse alphabet passing over neighbouring wires being audible in the Telephone, and another class can be traced to earth currents upon the wire, a curious modification of this sound revealing the presence of defective joints in the wire. Professor Blake informs me that he has been able to use the railroad track for conversational purposes in place of a telegraph wire ; and he further states that when only one Telephone was connected with the track the sounds of Morse operating were distinctly audible in the Telephone, although the nearest telegraph wires were at least 40 feet distant."

This remarkable result is described with more detail in the clever article in *Chambers's Journal*, already noticed. The writer, a gentleman of long experience in telegraphic research, says:—"In various recent articles on the Telephone, mention has been made of 'contact' as the cause of disturbance. This word, however, although it has been used by telegraphists, is misleading, and can only be used as an endeavour to express popularly an electric fact. Actual contact of one wire with another would spoil the business altogether. A wire bearing an electric current seems to be for the time surrounded, to an undefined distance, by an electric atmosphere, and all wires coming within this atmosphere have a current in an opposite direction set up in them. This is as near an explanation of the phenomena of induction as the state of telegraph science at present affords. Now the Telephone works with a very delicate magnetic current, and is easily overpowered by the action of a stronger current in any wire near which the Telephone wire may come. To work properly, it requires a silent line. In the place where the observations were made, there are a large number of wires, travelling under the floor, through the test-box, along passages to the battery-room and to a pole on the outside, whence they radiate, or out to a pipe underground, where many gutta-percha covered wires lie side by side. On applying the ear to a Telephone joined into a circuit working in such an office a curious sound is

heard, comparable most nearly to the sound of a pot boiling. But the practised ear could soon separate the boiling into distinct sounds. There was one masterful Morse instrument—probably on the wire lying nearest the one on which we were joined up—whose peremptory ‘click, cli-i-i-ck, click,’ representing ‘dot, dash, dot’ on the printed slip we read from, could be heard over all. Then there was the rapid whir of a Wheatstone fast-speed transmitter, sending dots and dashes at express speed by mechanical means; the sharp well-pronounced rattle in sounds of equal length of a needle instrument; and most curious of all, the ‘rrrrr-op, rr-op, rrrrrrrrrrrrrr-op, rrrrr-op, rr-op’ of the A B C, the deadliest foe to the Telephone in its endeavours to gain admission into the family of telegraph instruments. . . . It must not be understood that the *sounds* of those various instruments are actually heard in the Telephone. What happens is, that the currents stealing along the Telephone wire by induction produce vibrations in the diaphragm of that instrument, the little metal membrane working on the magnet in ready response to every current set up in the latter. When it is remembered that the principle of the Telephone is that the sound-caused vibrations in the filmy diaphragm at one end create similar but magnetically-caused vibrations in the diaphragm at the other end, and so reproduce the sound, it will be obvious why the rapid roll of the A B C currents, or the swift

sending of the fast-speed transmitter, when brought by induction into the Telephone wire, cause disturbances in the sound vibrations, and thereby cripple the instrument. One instrument of either kind named would have a certain effect, but one Morse or single needle would not have any greatly prejudicial effect. But a number of Morses or needles going together, such as were heard in our experiments, would combine to be nearly as bad as one A B C or fast-speed Morse."

The following extract from a letter which recently appeared in the *Daily News*, shows that inductive action, when the parallel circuits are not numerous, does not seriously interfere with the transmission of speech :—

"The experiments with the Telephone were made by me upon the cable lying between Dover and Calais, which is $21\frac{3}{4}$ miles long. Several gentlemen and ladies were present, and conversed in French and English with a second party in France for upwards of two hours. There was not the slightest failure during the whole time. I was only using one wire. The other three (it is a four-wire cable) were working directly with London and Paris, Calais, and Lille. I could distinctly hear the signals by the three wires on the Telephone, and at times when but one of the three wires was working, I could decipher the Morse signals, and read a message that was passing for Glasgow to Paris. Yet when

all the three wires were working simultaneously, the Telephone sounds were easily and clearly distinguishable above the click of the signals. I happened to know several of the party in France, and was able to recognise their voices. They also recognised mine, and told us immediately a lady spoke that it was a female voice. When making some trials upon a line three-fourths of a mile long, I arranged a musical-box (the tones of which are very feeble) under the receiver of an air-pump, the top of the receiver being open. Upon this opening I placed the Telephone, and every note came out at the second end so clearly as to enable those who were present to name the tune that was played. Unfortunately we had not the same means in France, but simply held the mouth of the Telephone close to the box, and some of the notes were audible, but not so perfect as on the short line. One young lady burst out laughing the moment she placed the instrument to her ear, and exclaimed, 'Some one is whistling "Tommy, make room for your Uncle!"' As my correspondent and myself had had a little practice, we were, without the slightest difficulty, able to talk in our usual manner, without any strain upon the voice, or any unnatural lengthening of syllables. We were not able to hear breathing, in consequence of the continued pecking caused by induction from other wires "

THE PHONOGRAPH—SENDING THE VOICE BY POST.

The announcement of the possibility of transmitting the voice by telegraph wires, has been followed by a new and even more wonderful announcement. Mr. Edison of New Jersey (an eminent telegraphic engineer, whose investigations we have noticed at page 36) has devised a method by which the voice can actually be imprinted on a thin slip of metal, and sent to any part by post, the tones being reproducible on another phonograph; so that parents, husbands and wives, children and sweethearts, may speak to those near and dear to them; and cooler business men may send messages *viva voce* to places as yet unreached by telegraph, and be secure from the possibility of the message being heard by any person other than the one to whom it is sent. This amazing invention will be best described by quoting the account of it given in the *Times* of Tuesday, the 15th of January, 1878 :—

“Not many weeks have passed since we were startled by the announcement that we could converse audibly with each other, although hundreds of miles apart, by means of so many miles of wire with a little electro magnet at each end, yet we are on the point of realising some of the many advantages promised

All About the Telephone

by the telephone. Another wonder is now promised us—an invention, purely mechanical in its nature, by means of which words spoken by the human voice can be, so to speak, stored up and reproduced at will over and over again, hundreds, it may be thousands, of times. What will be thought of a piece of mechanism by means of *which a message of any length can be spoken on to a plate of metal, that plate sent by post to any part of the world, and the message absolutely respoken in the very voice of the sender, purely by mechanical agency?* What, too, shall be said of a mere machine by means of which the old familiar voice of one who is no longer with us on earth can be heard speaking to us in the very tones and measure to which our ears were once accustomed?

“The highly ingenious apparatus by which this wonder is effected is the invention of Mr. Thomas A. Edison, of Manlowe Park, New Jersey, U.S.A., the electrical adviser to the Western Union Telegraph Company. Mr. Edison is well known in the States, and scarcely less so in England, for several valuable practical applications of electrical science, among Mr. Edison’s other inventions being an exceedingly well-arranged Telephone. To the present invention Mr. Edison has given the name of the Phonograph, and it depends for its action upon certain well-known laws in accoustics.

“The Phonograph is composed of three parts mainly—namely, a receiving, a recording, and a

transmitting apparatus. The receiving apparatus consists of a curved tube, one end of which is fitted with a mouthpiece, for the convenience of speaking into it. The other end is about two inches in diameter, and is closed in with a disc or diaphragm of exceedingly thin metal, capable of being thrust slightly outwards or vibrated upon gentle pressure being applied to it from within the tube. To the centre of this diaphragm—which forms a right angle with the horizon—is fixed a small blunt steel pin, which, of course, partakes of the vibratory motion of the diaphragm. This arrangement is carried on a table, and is fitted by a set screw, by means of which it can be adjusted relatively to the second part of the apparatus—the recorder. This is a brass cylinder, about four inches in length and four inches in diameter, cut with a continuous V groove from one end to the other, so that it in effect represents a large screw. Measuring along the cylinder from one end to the other, there are ten of these grooves to the inch, or about forty in the whole length. The total length of this continuous groove, or screw-thread, is about 42 feet—that is to say, that would be the length of the groove if it were stretched out in a straight line. This cylinder is mounted on a horizontal axis or shaft carried in bearings at either end, and having its circumferential face presented to the steel point of the receiving apparatus. The shaft is prolonged for four inches or so beyond the ends of

the cylinder, and one of the prolongations is cut with a screw thread, and works in a screwed bearing. This end terminates in a handle; and as this is turned round the cylinder is not only revolved, but, by means of the screwed spindle, is caused to travel its whole length in front of the steel point, either backwards or forwards.

“We now see that if the pointer be set in the groove in the cylinder at its commencement, and the handle turned, the groove would be traversed over the point from beginning to end, or, conversely, the point would always be presented to the groove. A voice speaking in the receiver would produce waves of sound which would cause the point to enter to greater or less depths into this groove, according to the degree of intensity given to the pressure upon the diaphragm set up by the vibrations of the sound produced. This, of course, of itself would mean nothing; but in order to arrest and preserve these sound-pressures, a sheet of tinfoil is interposed, the foil being inelastic and well adapted for receiving impressions. This sheet is placed around the cylinder and its edges lightly fastened together by mouth-glue, forming an endless band, and held on the cylinder at the edges by the india-rubber rings. If a person now speaks into the receiving tube and the handle of the cylinder be turned, it will be seen that the vibrations of the pointer will be impressed upon that portion of the tinfoil over the hollow groove and retained by it.

These impressions will be more or less deeply marked according to the modulations and inflexions of the speaker's voice. We have now a message verbally imprinted upon a slip of metal. Sound has, in fact, been converted into visible form, and we have now to translate that message by reconverting it into sound. We are about, in effect, to hear our own voice speaking from a machine the words which have just fallen from our lips. To do this we require the third portion of Mr. Edison's apparatus — the transmitter.

“ This consists of what may be called a conical metal drum, having its larger end open, the smaller end, which is about two inches in diameter, being covered with paper, which is stretched taut as is the parchment of a drum-head. Just in front of this paper diaphragm is a light flat steel spring, held in a vertical position and terminating in a blunt steel point projecting from it, and corresponding with that on the diaphragm of the receiver. The spring is connected with the paper diaphragm of the transmitter by means of a silken thread, which is placed just sufficiently in tension to cause the outer face of the diaphragm to assume a slightly convex form. This apparatus is placed on the opposite side of the cylinder to the receiver. Having set the latter apparatus back from the cylinder, and having, by turning the handle in a reverse direction, set the cylinder back to what we may term the zero point, the transmitting

apparatus is advanced towards the cylinder by means of a set screw until the steel point rests without absolute pressure in the first indentation made by the point of the receiver. If now the handle be turned at the same speed as it was when the message was being recorded, the steel point will follow the line of impression and will vibrate in periods corresponding to the impressions previously produced on the foil by the point of the receiving apparatus. Vibrations of the requisite number and depth being thus communicated to the upper diaphragm, there will be produced precisely the same sounds that in the first instance were required to produce the impressions formed on the tinfoil. Thus the words of the speaker will be heard issuing from the conical drum in his own voice, tinged, however, with a slight metallic or mechanical tone. If the cylinder be revolved more slowly than when the message was being recorded, the voice assumes a bass tone ; if more quickly, the message is given with a childish treble. These variations occur according as the vibrations are more or less frequent.

“Such is the apparatus, and it promises to be one of the most remarkable of the recent marvels of science. The machine we have described is the first Mr. Edison has made, but he is now constructing one to be set in motion by clockwork, the cylinder being 16 inches long. In the present machine, for recording a long message, as soon as one strip of the tinfoil is filled it is removed and replaced

by others until the communication has been completed. In using the machine for the purpose of correspondence, the metal strips are removed from the cylinder and sent to the person with whom the speaker desires to correspond, and who must possess a machine similar to that used by the sender. The person receiving the strips places them in turn on the cylinder of his apparatus, applies the transmitter, and puts the cylinder in motion, when he hears his friend's voice speaking to him from the indented metal. And he can repeat the contents of the missive as often as he pleases until he has worn the metal through. The sender can make an indefinite number of copies of his communication by taking a plaster of Paris cast of the original strip and rubbing off impressions from it on a clean sheet of foil. It will thus be seen, as we stated at the commencement of this article, that the voices of those who have left us, either for ever or for a season only, can be heard talking with us if we so desire it. The invention has been so recently and so quickly developed into existence by Mr. Edison that he himself can hardly say what its practical value is or will prove to be. Numerous applications suggest themselves, but beyond those which we have alluded it is difficult to say with precision how they would work out in practice. In cases of depositions it might be of the highest importance to have oral evidence mechanically reproduced in a court of justice. Authors, too, may perhaps be saved the trouble of writing their compositions."

A gentleman writes from New Jersey:—

“Mr. Edison has improved this instrument greatly. The sounds are reproduced by the same diaphragm as you speak against, and are very much reinforced by the application of a large funnel-shaped tube to the mouthpiece. By means of this tube the reproduction of ordinary conversation can be heard distinctly 100 feet away. The machine, as exhibited last Monday, was a perfect success, whistling, singing, whispering, &c., being reproduced accurately, and the more difficult sounds, such as the “S’s,” and the “sh” in “shall,” the “ve” in “valve,” and all those we found difficulty in overcoming on the Telephone, came clear and distinct. President Orton and others tested the instrument’s powers of repeating spoken words. On one occasion three gentlemen spoke in succession—the first in English, the second in Spanish, and the third in Hungarian—and the machine repeated the words so as to be heard distinctly by a dozen persons standing around the apparatus. “Old Uncle Ned” and a verse of a Spanish love song were next sung, and reproduced by the instrument to the satisfaction of all. Mr. Edison says the machine is designed for practical use by business men and lawyers, &c. He is now making a new machine which will have a plate sufficiently large to receive 500 spoken words. Thus a man may dictate half a dozen letters before leaving his office, and his clerks may write them out in his

absence. If he should wish to say more, he can remove the first plate and put in a second, and so on up to any number he may require."

The *English Mechanic* of January 25th, 1878, says :—

"Mr. Edison's Phonograph is progressing steadily towards a practical degree of perfection. Thanks to the courtesy of Mr. G. B. Scott, the superintendent of the Gold and Stock Telegraph Company of New York, we have been enabled to study a strip of tin-foil taken from the cylinder of the Phonograph. Notwithstanding the vicissitudes of a Transatlantic voyage, the series of indentations made by the vibrations made by the point were quite distinct. It is practically impossible to convey a correct idea of the different appearances of the groups of indentations, the dotted and plain rules employed as a diagram by some of our contemporaries failing entirely as a representation of a Phonograph sheet. The insulations are slight and deep, varying between the result of the faintest touch of a whisper and the energetic punch of some aspirated syllable ; they are moreover grouped in twos and threes, the members of the groups being sometimes joined (osculating), and at others separated ; while both long and short intervals occur between them. Here and there the indentations takes the form of a plain line, which, on closer inspection, betrays the presence of a slight ripple in parts."

USES OF THE TELEPHONE AND PHONOGRAPH.

The most obvious use is the sending messages, telegraphic fashion, long distances ; but other important applications of the principle have already been made. The Telephone is already in use in coal mines, recording not only the words of the human voice—a sufficiently important matter, considering the distance from the surface at which miners work, and the difficulty of rapid communication—but the varying pressure of atmospheric air and subterranean gases, a service of great value as a means of ascertaining the presence of danger. The Telephone is made to repeat the sound produced by a piece of spring vibrated at every tenth revolution of an anemometer (or instrument for registering the pressure of the atmosphere), by suitable mechanism, and situated in close proximity to the pole of a magnet, beside which it vibrates without even actually touching it. A coil surrounding this magnet is joined up in the usual way to wires leading to the Telephone, and it is found that every “tick” of the steel spring is heard in the Telephone. This is the joint invention of Mr. A. Le Neve Foster, of the Silvertown Telegraph Company, and Mr. H. Hall, one of H. M.’s Inspectors of Mines.

Telephonic communication has also been made with divers, the method being thus described by Professor Bell :—

“Inside the diver’s helmet you place a Telephone of convenient structure, and in the place of using a separate telegraph wire we use the wire that is coiled up inside the breathing pipe. In every breathing pipe of course there must be a coil of wire, in order to withstand the pressure of the water, and that wire we find can be used for the purposes of the Telephone, so that the wire inside this pipe is connected with the Telephone inside the diver’s helmet, and the earth connection is simply made by attaching the other wire to the helmet itself, which is in contact, outside, with the salt water. I had the pleasure of trying to converse with a diver with perfect success at Messrs. Siebe and Gorman’s, in a tank. He heard every word I said, and I was able to understand every word he said ; and when I told him to come up, by word of mouth, he obeyed me.”

A writer in *The Commercial Travellers’ Gazette* says :—

“It is quite within the reach of moderate expectation that before many months have passed the chief commercial hotels will have telephones fitted, so that principals at home may communicate with travellers as readily as the heads of the firm in the counting-house can send an order through the familiar speaking tube to a warehouseman in an upper story. Hood, in

one of his comic poems, makes a pedlar praise the powers of an ear-trumpet he wanted to sell by averring that he sold one to a deaf woman, 'and the very next day she heard from her husband at Botany Bay ;' but the Telephone will beat that. The Commercial's peace of mind may, perhaps, be a little disturbed if, when he has returned after his day's round to his snug quarters in the Commercial Room, the 'governor' in London should be inclined to be chatty, and transmit a string of questions as to what the day's business is worth ; whether old Brown has been easily got at for a good line, or Jones and Smith have been in an amiable and buying mood. In such cases the recording or printing instrument had better be used, as the wrong man might put his ear to the metallic disc, or perhaps send back a reply more humorous than appropriate ; or it might be, if very audacious, and the dinner had been inspiring, transmit to the prosaic inquirer a verse of the song which had just set the table in a roar. The affectionate family man, by the necessities of commerce far away from home, would, of course, be delighted to have a word from the partner of his joys and sorrows ; and how sweet to hear the little ones lisp 'Good night,' or even to hear the baby cry, and so be assured that its lungs are sound, through the medium of this wonderful Hotel-phone—if we may be pardoned for so designating it."

As to the extent to which the Phonograph can be

made available, it is not easy to keep on the safe side of exaggeration. Many people keep old letters—lovers, we have heard, delight to read tender epistles over and over again ; but now they can *treasure up old voices* !—preserve the little metal slip, and hear again and again the words so dear, and the tones still dearer. The last utterances of a dearly-loved parent, child, or friend may be treasured and listened to, though continents and oceans intervene.

Will phonographic slips be used as Christmas and New Year cards? or—how charming the idea!—as Valentines? It may be ; and, if so, a new style of verses may be required—something of this kind :—

“ Will you, dearest, be my own ?
Tell me through the Tell-e-phone.”

Or, more sentimentally :

“ Speak but one word, and bid my heart rejoice,
One little word, of all words loved the most ;
Let me but hear it in my darling’s voice—
And please transmit it by this evening’s post.
I cannot see you smile, but if you laugh,
Shall hear the merry tones by Phonograph.”

THE END.

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